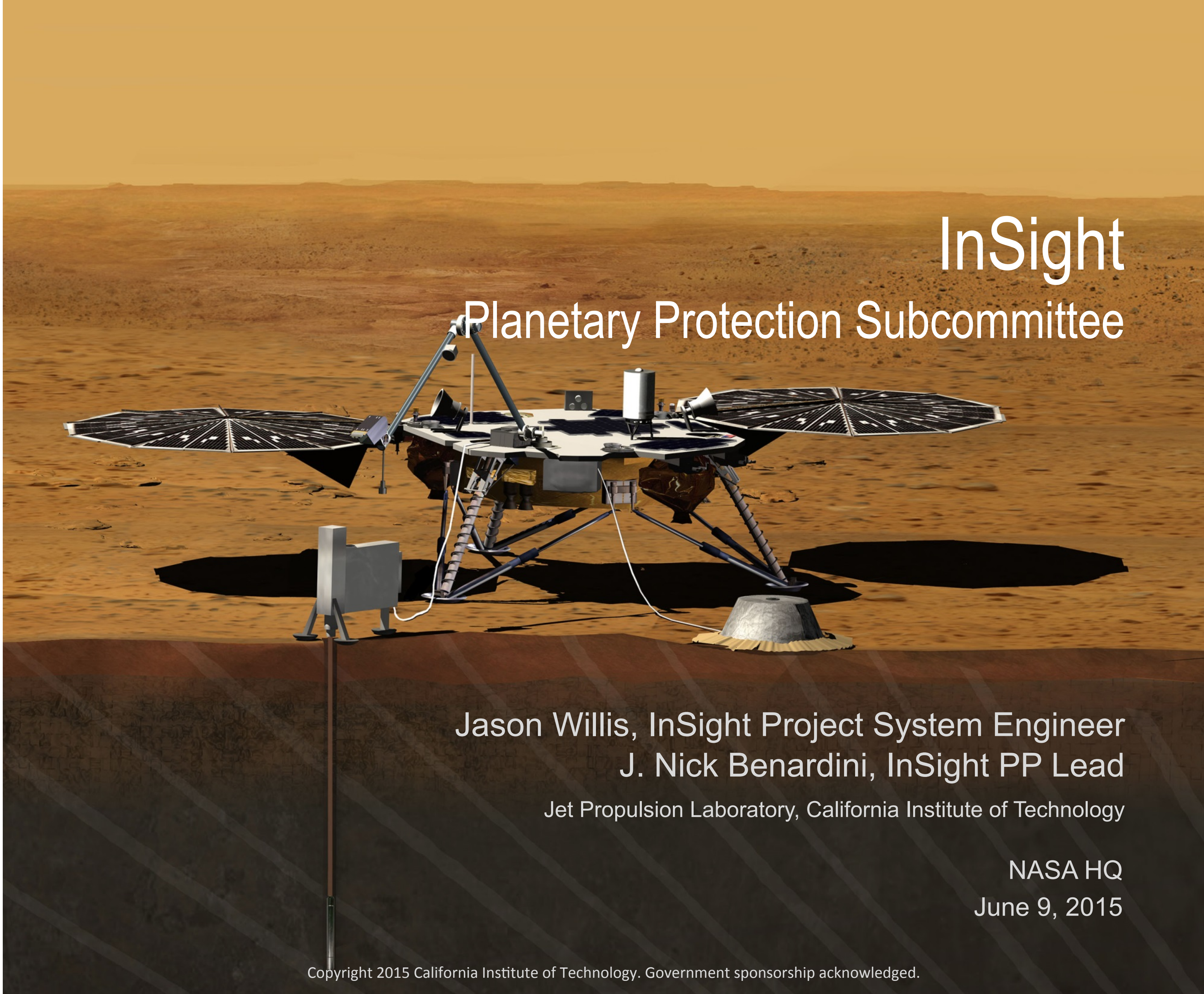


InSight

Planetary Protection Subcommittee

Jason Willis, InSight Project System Engineer

J. Nick Benardini, InSight PP Lead

Jet Propulsion Laboratory, California Institute of Technology

NASA HQ

June 9, 2015

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Overview

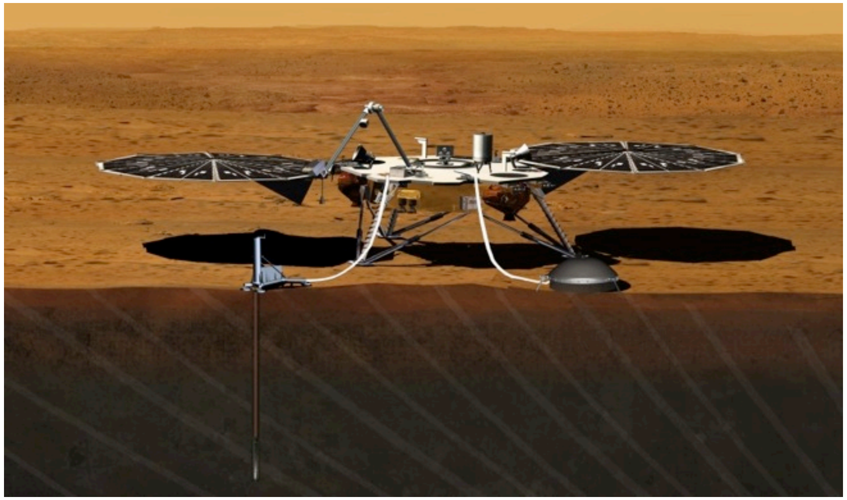
- Mission highlights
  - Payload
  - Landing Site
  - Timeline
- PP Requirements
- PP Status Update

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

InSight Project Overview

Salient Features

- Category: 2; Risk Class: B
- Mars Lander based on Phoenix heritage
- Science instruments contributed from CNES (SEIS) and DLR (HP^3)
- Launch Period March 4-30, 2016, on ATLAS V 401
- 6.5-month cruise, type 1 trajectory, direct entry
- Landing on Sept. 28, 2016, followed by one Martian year of science measurements on the surface



Science

1. Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars by determining:

- The size, composition and physical state (liquid/solid) of the core
- The thickness and structure of the crust
- The composition and structure of the mantle.
- The thermal state of the interior

2. Determine the present level of tectonic activity and meteorite impact rate on Mars by measuring:

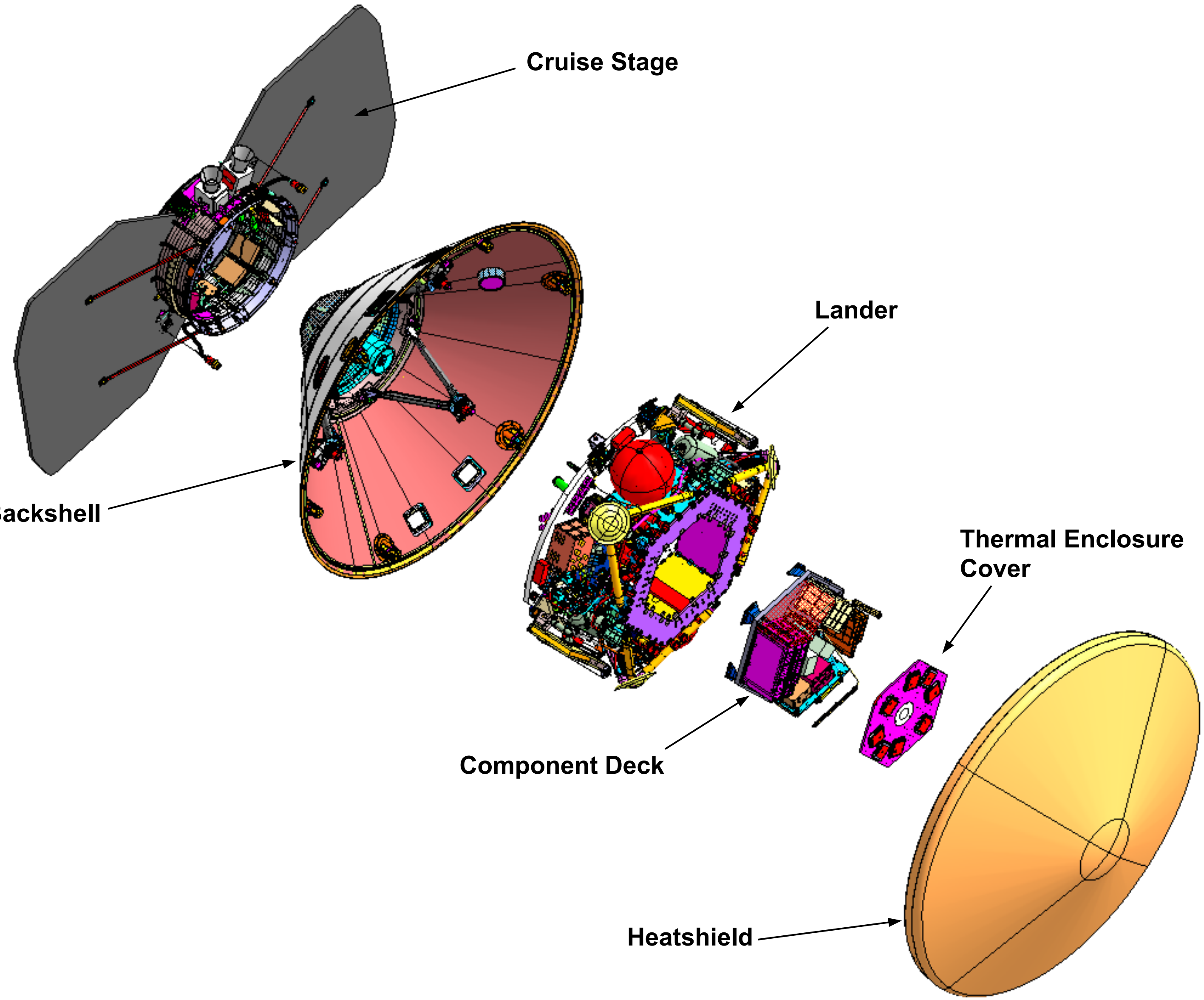
- The magnitude, rate and geographical distribution of internal seismic activity
- The rate of meteorite impacts on the surface

Payload

- SEIS – Broad-band seismometer: Measures seismic waves from 0.01 mHz to 50 Hz to determine the planet's interior structure
- HP^3 – Heat Flow and Physical Properties Package: Measures subsurface thermal gradient and conductivity to determine planetary heat flow
- RISE – Rotation and Interior Structure Experiment: Uses S/C communication system to measure rotational variations of Mars
- IDS – Instrument Deployment System: Robotic arm and cameras to deploy SEIS and HP^3 to the surface
- APSS – Auxiliary Payload Sensor Subsystem: Environmental sensors (wind, pressure, and magnetic field) to support the SEIS experiment

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

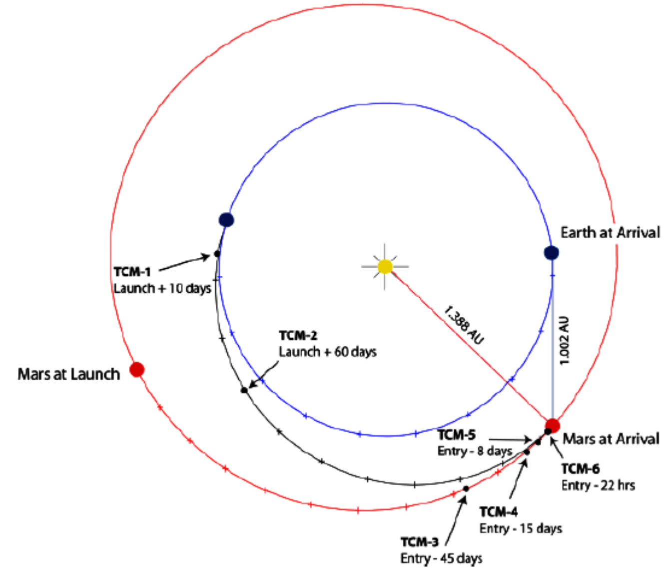
Flight System

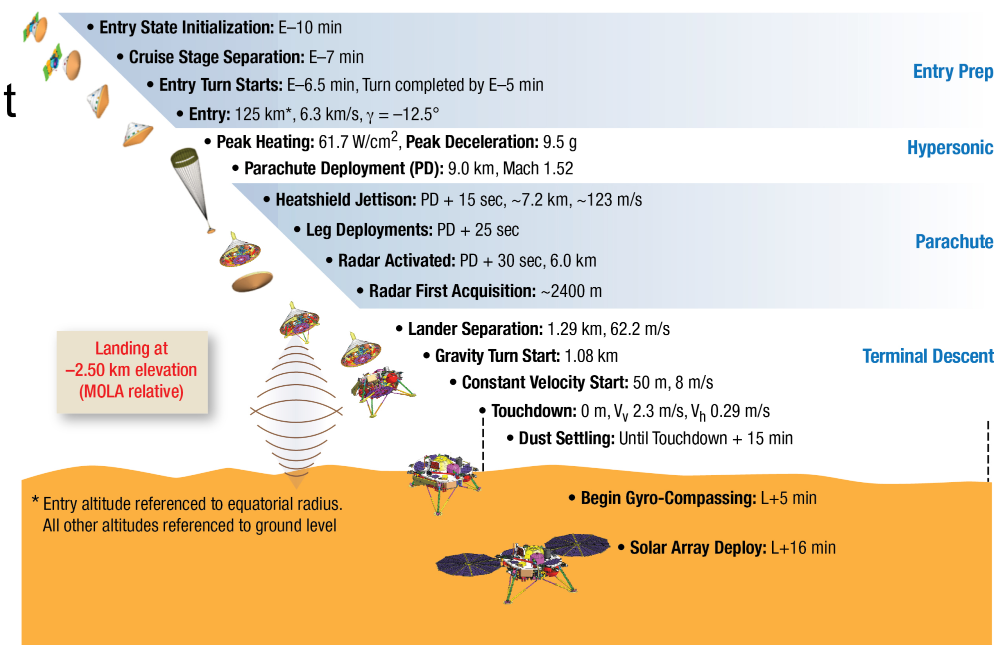


Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Launch, Cruise, and EDL Phases

- 27-day launch period opening on 4 March 2016
  - Launch vehicle will be Atlas V 501
  - Constant arrival date of 28 September 2016
  - Assumes MRO node move to 2:30PM for robust EDL Comm
- Type 1 transfer from Earth to Mars with 6.5-month Cruise Phase
  - EDL delivery accuracy is dependent on ESA (or JAXA) DDORs
- InSight EDL design is within the heritage capabilities
  - Higher entry speed and elevation
  - Landing region already selected—Elysium Planitia





Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

InSight Payload

Small Deep Space Transponder

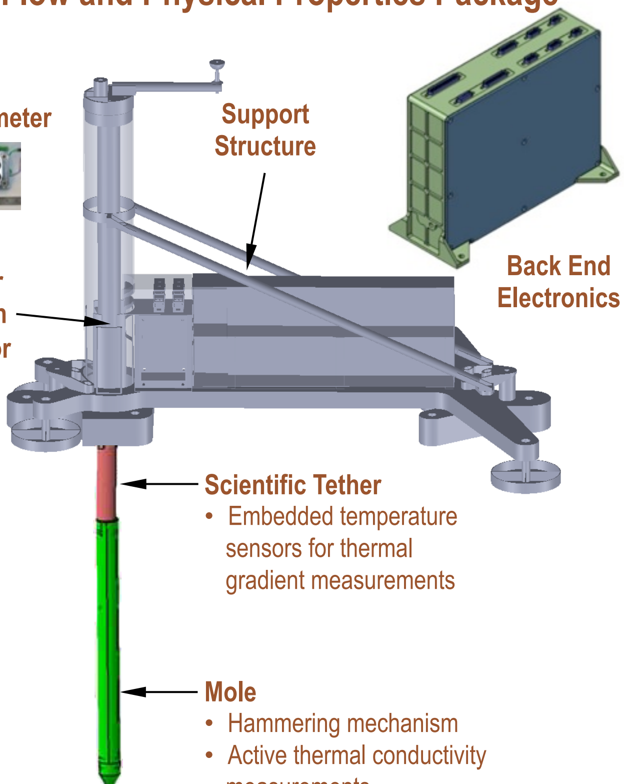
RISE (S/C Telecom)

Rotation and Interior Structure Experiment

HP^3 (DLR)

Heat Flow and Physical Properties Package

Radiometer



Support Structure

Back End Electronics

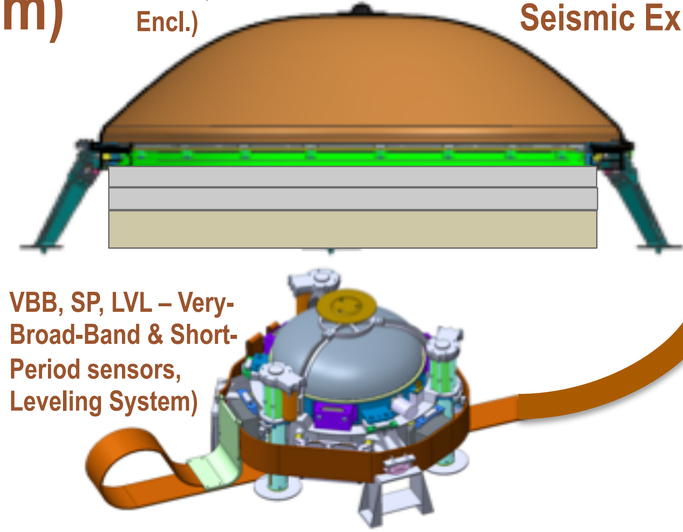
Tether Length Monitor

Scientific Tether
- Embedded temperature sensors for thermal gradient measurements

Mole
- Hammering mechanism
- Active thermal conductivity measurements
- Static tilt sensors

SEIS (CNES) (also IPGP, ETH/SSA, MPS/DLR, IC/Oxford/UKSA, JPL/NASA)

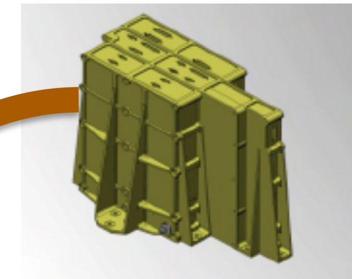
Seismic Experiment for Interior Structure



WTS, RWEB (Wind & Thermal Shield, Remote Warm Elect. Encl.)

VBB, SP, LVL – Very-Broad-Band & Short-Period sensors, Leveling System)

THR – Tether

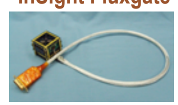


Ebox – Electronics Box

APSS (JPL)

Auxiliary Payload Sensor Suite

IFG (UCLA) InSight Fluxgate

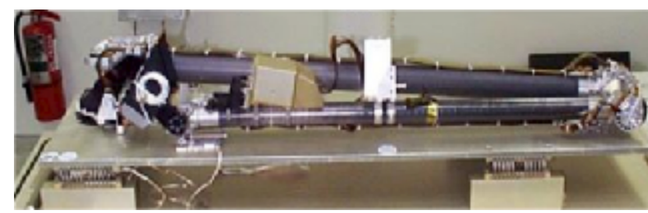


Pressure Sensor

TWINS (CAB) – Temp. and Wind for INSight

IDS (JPL)

Instrument Deployment System



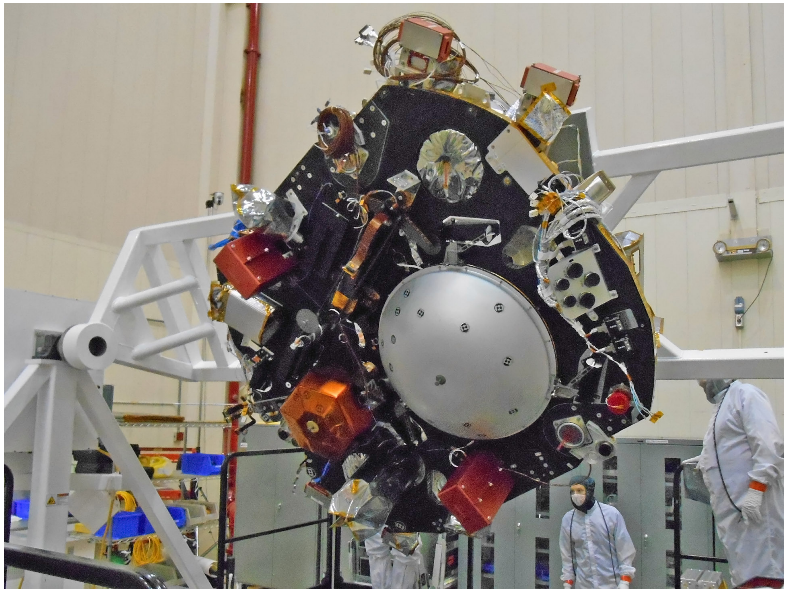
IDA – Instrument Deployment Arm

IDC – Instrument Deployment Camera

ICC – Instrument Context Camera

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

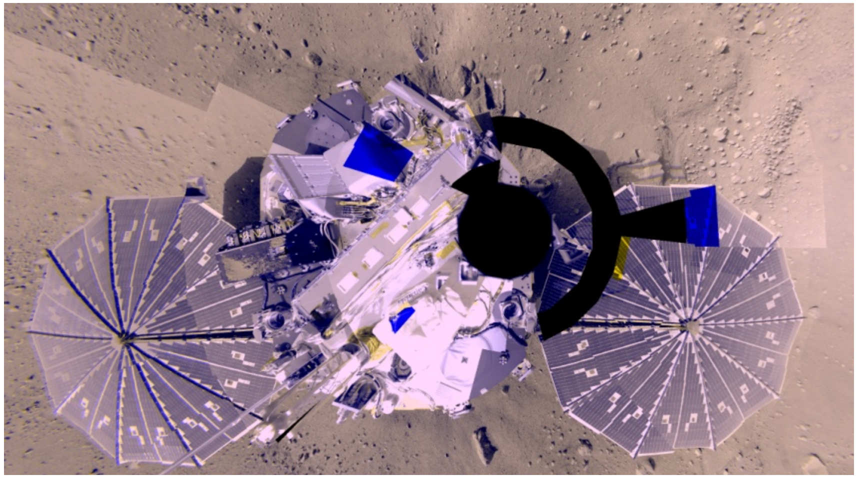
Spacecraft Updates



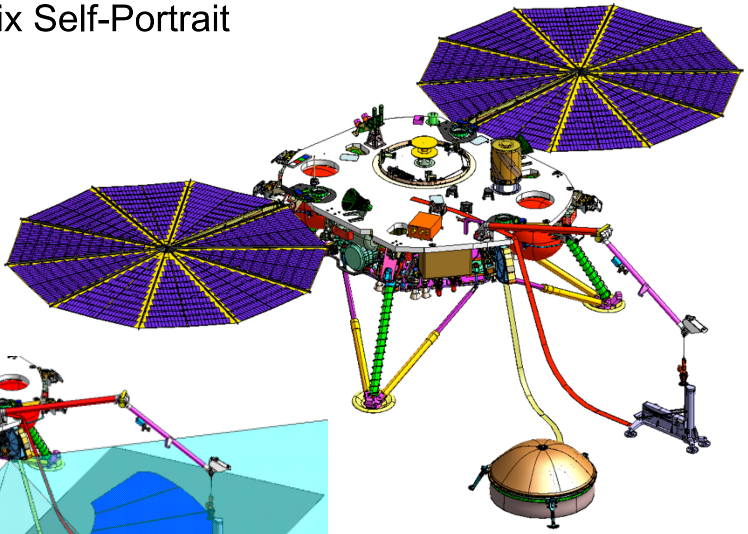
Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

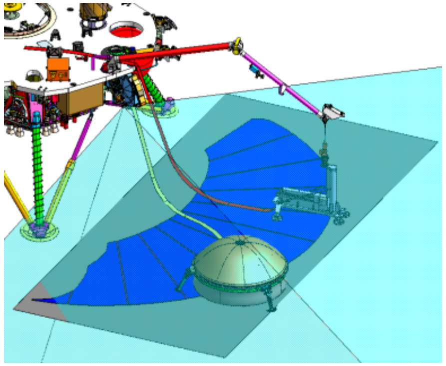
Surface Deployment and Science Monitoring

- 67-sol instrument deployment period
  - 22 days of built in margin
  - Science starts on sol 7 (RISE)
  - No strict time constraint for deployment
- Operational support
  - Full-team tactical operations during deployment
  - Using heritage MOS/GDS tools and processes
- One full martian year of science monitoring
  - Only minimal support team needed during science operations
  - Technical margins for operations are in good shape



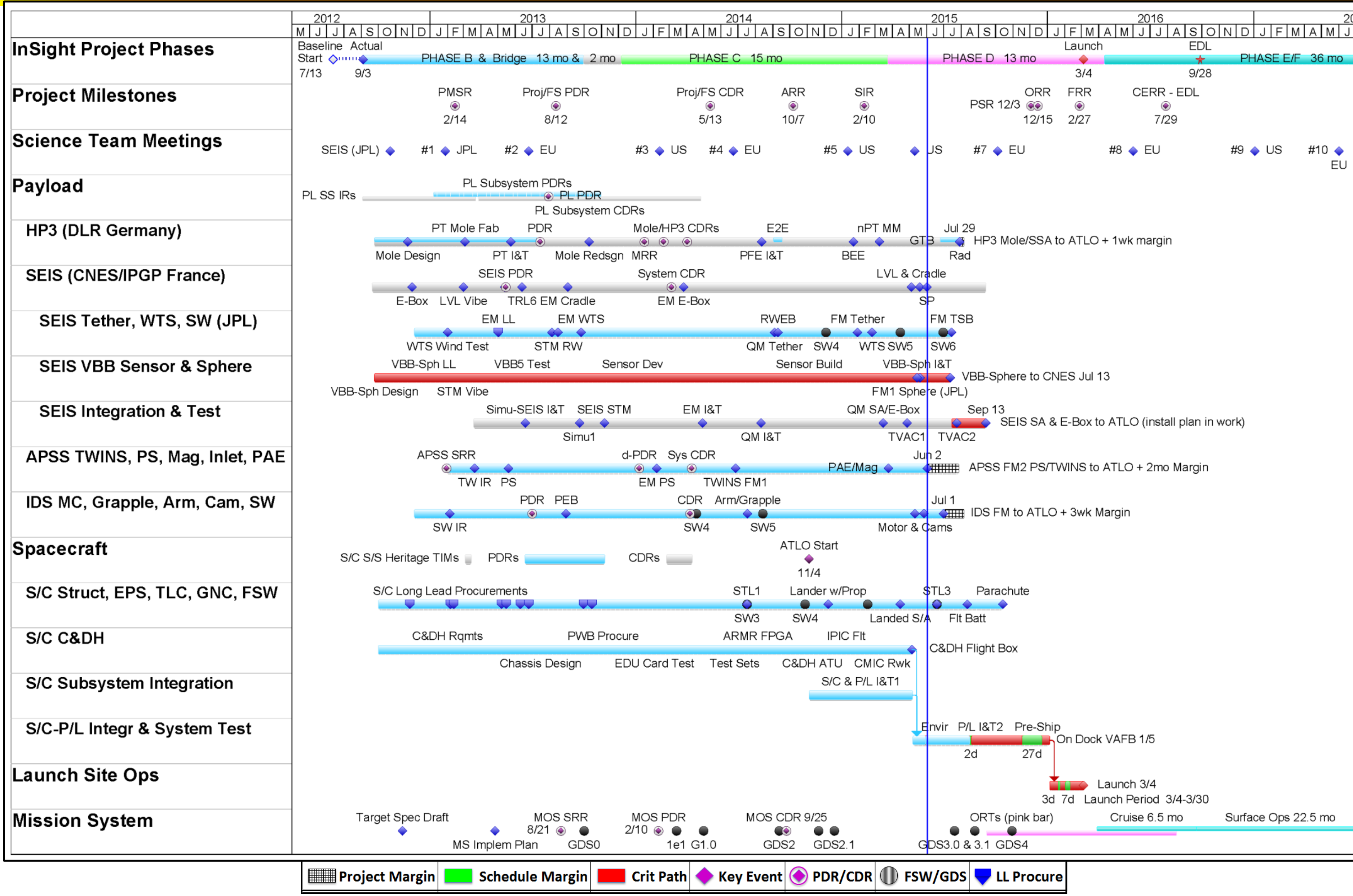
Phoenix Self-Portrait





Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

InSight Phase B-E Schedule



Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

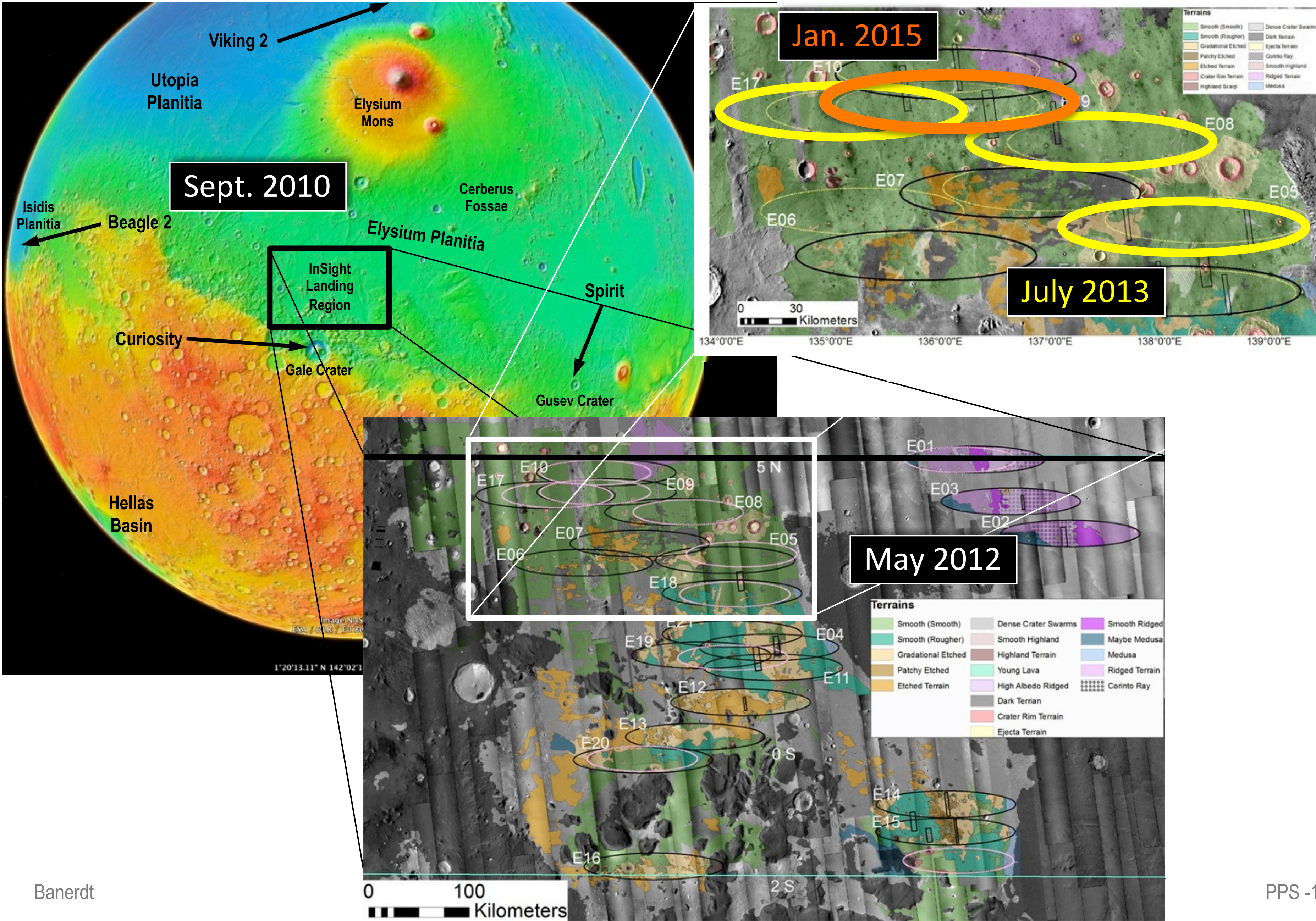
Landing Site Constraints

- **Latitude:** 15°S to 5°N: Sufficient Solar Power Margins
  - 3°N to 5°N Elysium Planitia (takes advantage of the northern latitudes)
- **Elevation:** <−2.5 km MOLA: Sufficient Atmosphere for EDL
- **Ellipse Size:** 139 km × 27 km [99.5% ellipse]
- **Thermal Inertia:** >100−140 J m^{-2} K^{-1} $s^{-1/2}$
  - Avoid surfaces with thick dust that is not loading bearing
  - Prefer ~200 J m^{-2} K^{-1} $s^{-1/2}$ for uncemented or poorly cemented soil
  - Radar reflective surface
- **Rock Abundance:** <10%
  - 99% Safe Landing and Opening Solar Panels
- **Smooth Flat Surface:** No large relief features
  - Slopes <15° for Safe Touchdown and Radar Tracking (1-5 m & 84 m)
- **Deploy Instruments: [<10% Rock Abundance, <15° Slope]**
- **Broken up regolith >5 m thick:** Hesperian Cratered Surface
  - Penetration of the Mole

No Planetary Protection Concerns for Landing Site = No Special Region!
No Other Science Requirements: Just Land Safely

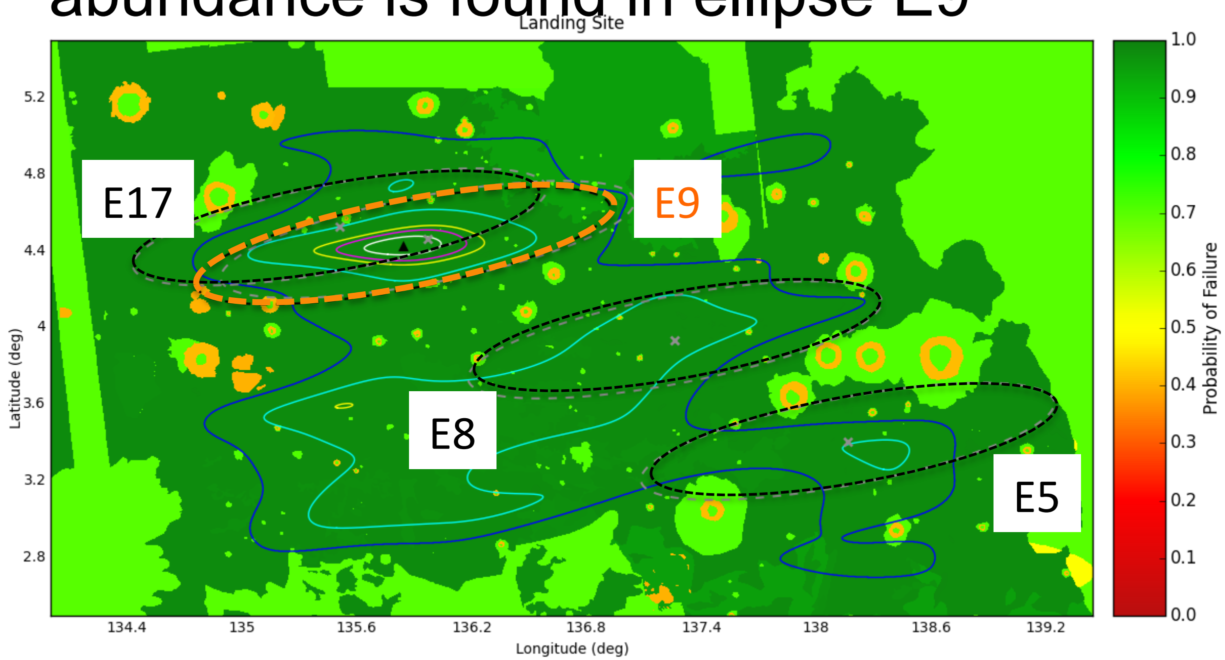
Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Landing Site – Selected One Prime Candidate



Final Site Selection Summary

- All four sites meet all engineering constraints
  - Latitude, elevation, ellipse, rocks, slopes, load bearing, radar reflectivity, instrument deployment, regolith >5 m thick
- Geologically mapped "Smooth Terrain" is the most benign terrain type – lowest rock abundance and slopes
- Greatest coverage by smooth terrain and lowest rock abundance is found in ellipse E9



Hazard map showing landing success probability contours at opening of launch period.

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

PP Requirements

- As a Mars lander mission without life detection instruments, the InSight mission has been designated **<u>PP Category IVa</u>** by the NASA PPO.
- In accordance with the requirements stated in NPR 8020.12D for this category and type of mission, the InSight Project will comply with:
  - Bioburden requirements, *i.e.,* $\leq 5 \times 10^5$ total spores at launch, 3×10^5 total spores on planned landing hardware, a mean exposed surface density of 300 spores/m^2
  - Assembly and testing in ISO 8 (or better) cleanroom environments
  - Launch environment cleanliness and recontamination avoidance – hardware cleanliness and launch recontamination not to exceed bioburden requirements
  - Organic inventory – bulk inventory of at least 50 grams of each organic material type for which more than 25 kg is transported to Mars and documentation of organic materials for which are present in quantities of 1kg
  - Probability of Impact – Launch vehicle Mars avoidance of less than 10^{-4} for 50 years after launch, and probability of a non-nominal impact of Mars by the spacecraft due to cruise phase failure shall not exceed a 10^{-2}

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

PP Requirements

- Additional Project requirements to include:
  - Average internal (behind HEPA or tortuous path) bioburden ≤ 1,000 spores/m^2
  - Mole shall be unpowered and cease operations immediately if tether breaks
  - Ice shall not be present within reach of HP^3 instrument's mole
  - Mole shall not generate a thin liquid film as a result of operations sufficient enough to transport a 50 nm particle.
  - Planetary Protection Landing Site Review Required
- Utilizing NASA PPO provided "new" heat microbial reduction specifications which provide expanded implementation options (*e.g.*, no humidity constraints, credit for manufacturing credit)
- All PP requirements have been captured into the Level 2 Project System Requirement Document [first Project to capture all PP requirements into Dynamic Object Oriented Requirements (DOORS) V&V tool].
- All Level 2 and 3 requirements are under Project Change Control Board management.

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Planetary Protection

- The project is currently in compliance with all PP requirements!
- Project continues formal and informal interactions with the NASA PPO
- PP assays in progress at JPL, LM, CNES, and DLR
  - Three NASA PPO verification assays completed; one at JPL, two at LM
  - All PPO verification assay events negotiated and actively tracking through schedule shifts
  - 130 sampling events completed totaling 952 swabs, 330 wipes, and 12033 petri dishes
  - All final assays have met required bioburden allocations and all verification assays passed
  - Verification assay planned prior to delivery at both DLR and CNES prior to delivery of HP3 and SEIS. Verification assays are planned at delivery inspection upon delivery at LM.
- Actively involved in payload rework by assessing revised implementation approaches, conducting additional assays to verify compliance, and updating PP assay schedule.
- Impacts of the MarCo launch vehicle secondary payload being evaluated.
- Launch Operations
  - PP Pathfinders (6) have been conducted to understand West Coast launch operations, characterize launch vehicle cleanliness, and assess changed or modified ULA processes and practices.
  - Dedicated PP lab at VAFB planned for support of SC and LV operations.

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Current Bioburden Estimate

- Compliance with all bioburden requirements
  - While bioburden has increased slightly since SIR, there still is >33% margin for all L2 and L3 bioburden requirements

Spacecraft Zone	Accountable Surface Area (m^2)	Accountable Volume (cm^3)	Maximum Allocated (at Launch) Spore Bioburden (spores)
Lander	**225.19**		**2.11E+04**
Landed Hardware	225.19		2.11E+04
Impacting Hardware — Planned			
Aeroshell	**811.20**	**1.29E+05**	**1.13E+05**
Landed Hardware	346.60		5.31E+04
Impacting Hardware — Planned	465	1.29E+05	5.96E+04
Parachute, landed hardware	**325.90**		**3.26E+04**
Cruise Stage	**33.12**	**0**	**5.00E+04**
Landed Hardware			
Impacting Hardware — Planned	33		5.00E+04
Subtotal surfaces, m^2	1395	—	
Subtotal volumes, cm^3		1.29E+05	
Small Misc	tbd	tbd	4.00E+04
Requirement		**300 sp/m2**	5.00E+05
Total		**141 sp/m2**	2.56E+05
Reserve			2.44E+05

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Looking ahead…

- Instrument Deliveries to ATLO – 7/15 – 9/15
- Move-in Date for PP Lab at VAFB – 9/15/15
- PP Landing Site Review – ~10/15/15
- Combined PP Pre-launch and Pre-ship Review – 12/16/16
- Spacecraft On Dock at VAFB -1/16
- Flight Readiness Review 2/29/16
- Launch – 3/4/16

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

InSight Planetary Protection Team

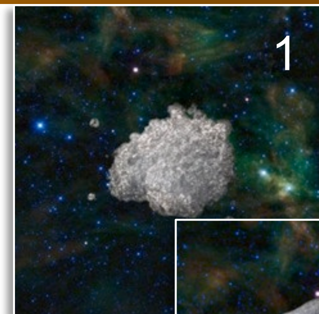
- **JPL**
  - Moogega Cooper
  - Gayane Kazarians
  - Fei Chen
  - Parag Vaishampayan
- **LM**
  - Joe Witte, LM PP Lead
  - Amy Baker
  - Patrick Bevins
  - Dennis Vaughn
  - Ray (Jamie) Woodzell
- **CNES**
  - Christian Martin
  - Delphine Faye
- **DLR**
  - Matt Dalton
  - Petra Rettberg

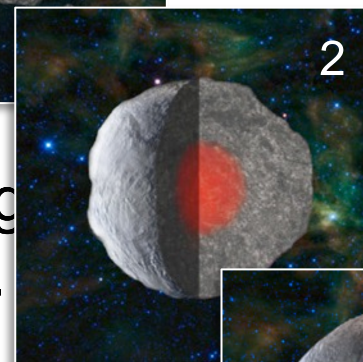
Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Backup

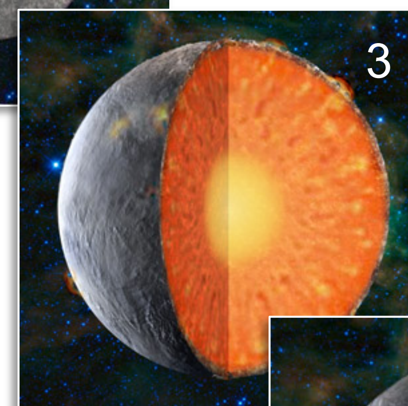
Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

How Does a Terrestrial Planet Form?



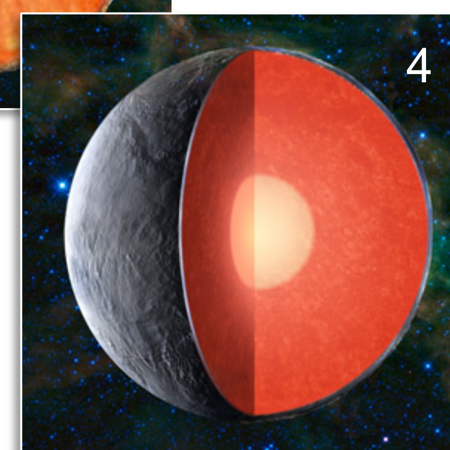


1. The planet starts forming throug
   accretion of meteoritic material.



2. As it grows, the interior begins to heat
   up and melt.

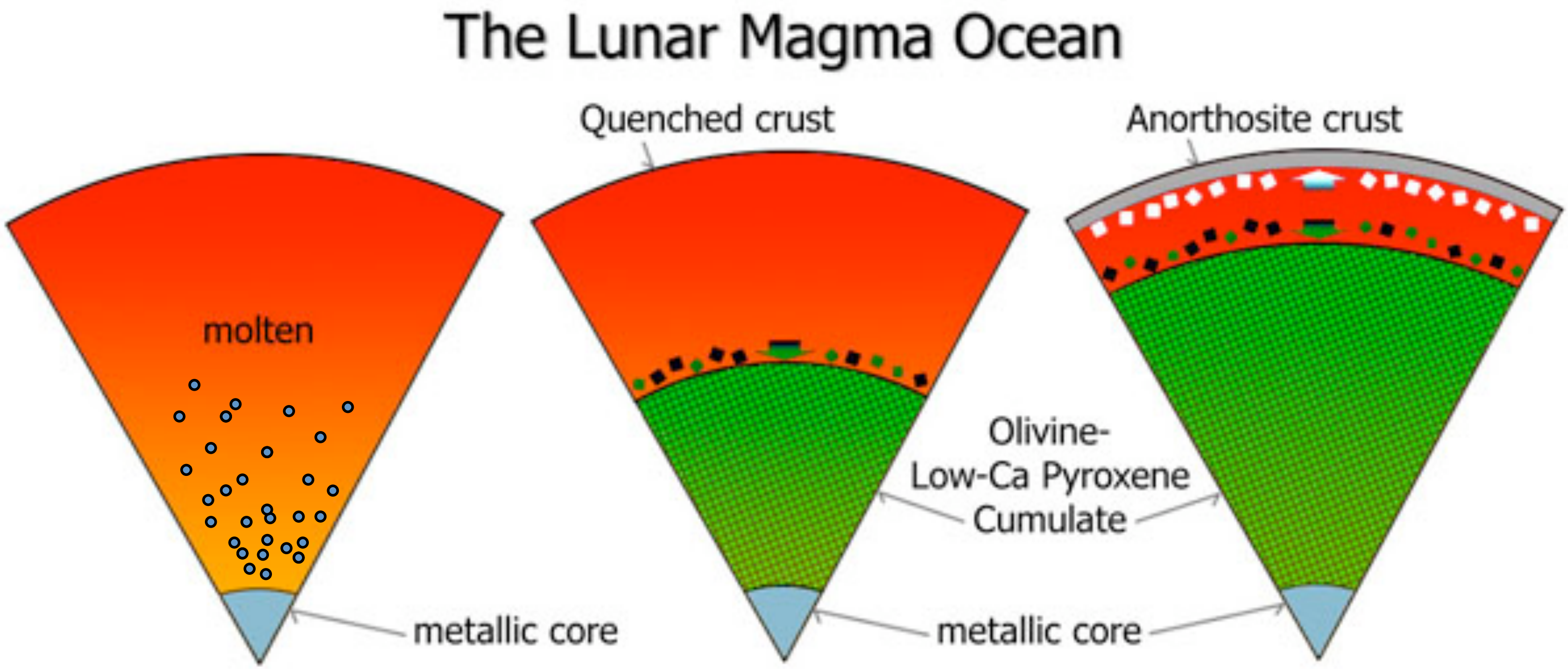
3 Stuff happens! ← **InSight!**



4. The planet ends up with a crust,
   mantle, and core with distinct, non-
   meteoritic compositions.

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Differentiation in a Terrestrial Planet

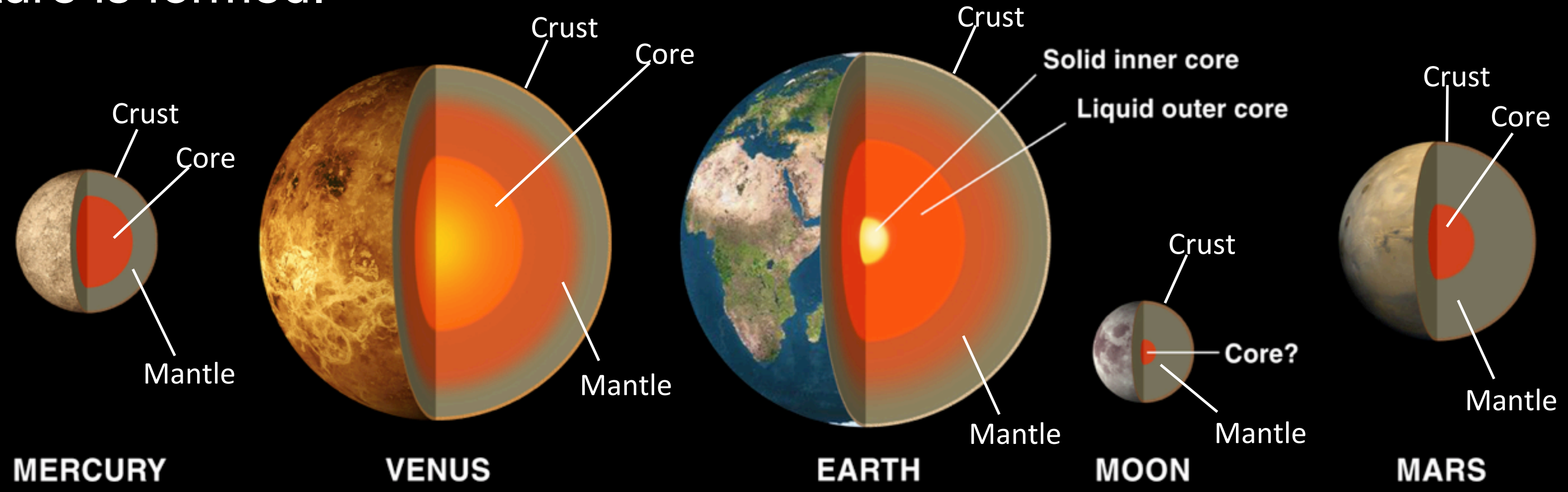


- Our understanding of planetary differentiation is largely based on the lunar magma ocean model, which was developed in response to Apollo geochemical and geophysical data. But…
  - This is a complex process; the physics is not well understood and present constraints are limited.
  - Lunar P-T conditions are not particularly representative of other terrestrial planets.

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.

Mars is Key to Understanding Early Formation of Terrestrial Planets, Including Rocky Exoplanets

Terrestrial planets all share a common structural framework (crust, mantle, core), which is developed very shortly after formation and which determines subsequent evolution. We seek to understanding the processes by which this structure is formed.



Mars is uniquely well-suited to study the common processes that shape all rocky planets and govern their basic habitability.

- There is strong evidence that its basic crust and mantle structure have survived little changed from the first few hundred Myr of formation.
- Its surface is much more accessible than Mercury, Venus.
- Our knowledge of its geology, chemistry, climate history provides a rich scientific context for using interior information to increase our understanding of the solar system.

Copyright 2015 California Institute of Technology. Government sponsorship acknowledged.